These pages show that we are allowing Americans to be exposed to levels 4 to 12 fold higher than those levels which the Soviets exposed Americans at the U.S. Embassy in Moscow.

Enclosed are:

o Engineering reports showing the predicted exposure levels at 3 mobile telecommunication cell sites in Seattle, Washington. The maximum predicted exposures are

Microwatts per square centimeter of area	Neighborhood Location
23	Laurelhurst
30	Ravenna
62	Edgewater

o Page 5-115 of the EPA report, Biological Effects of Radiofrequency Radiation, 1984, EPA-600/8-83-026F which gives the exposure levels at the U.S. Moscow embassy. Note that for 23 years, from 1953 to May 1975 the exposure levels **did not exceed 5 microwatts per square centimeter.**

Therefore the exposure levels for the above 3 Seattle neighborhoods are 4, 6, and 12 fold higher than that which the Soviets irradiated the U.S. Moscow embassy.

Note that the EPA reports there was a 3 fold increase in protozonal infections than in comparison post employees, and that, "In general both sexes in the Moscow group had somewhat higher frequencies of most of the common kinds of health conditions reported."

The author reported that location in the embassy was not related to incidence rates. The relevance of this is not clear since only half of those sent questionaires reported, and also since location during work hours may not reflect residence location after work hours. Also, some persons may have higher sensitivies than others. In addition, studies in vitro of the effect of radiofrequency on calcium efflux ions of chick brain shows that effects sometimes occur at lower levels and not at higher levels
[see above EPA study page 5-88-5-93; EPA notes this phenomena of effects at lower levels but not at higher ones "may prohibit the invocation of threshold levels (page 5-92)." Thus, the observed fact of higher incidence rates at the microwave irradiated U.S. Moscow embassy is the key fact to consider.]

o Page 16 of the report of Dr. Neil Cherry on the epidemiological study of the U.S. Moscow embassy by Dr. John Goldsmith finding that there was a statistically significant increase in the white blood cell counts, mean hematocrit increased, and a threefold increase in monocyte count.

He reports there were also raised cancer deaths (15 out of 31 women staff, including leudkmia, famale genitalia cancer, and child cancer. [from Goldsmith, J.R. 1995: Epidemiological Evidence of Radiofrequency Radiation (Microwave) Effects on Health in Military, Broadcasting, and Occupational Studies. International Journal of Environmental Health, 1, pp 47-57, 1995 (note elsewhere the name of the journal has been given as International Journal of Occupational and Environmental Health)]

o Page 128-129 from The Zapping of America by Paul Brodeur, 1977, W.W.Norton, in which it is documented that the white blood cell lymphocyte counts ran 44% higher than normal in 64 out of 213 American diplomats.

Also, that Zbigniew Brzezinski, the national security advisor to President Carter, reported to Paul Brodeur that,

"The cancer rate among Americans at the Moscow embassy was the highest in the world."

Cellular Power Density for the Edgewater Cell Site.

Prepared by Roy Norgaard 10/11/94

Antenna Height:	35 feet	ERP/Chan:	100 watts
Measurement Ht:	6 feet	Antenna:	DB 833R
Number of Radio Chs	30		

Distance From Tower (Feet)	Adjusted Vertical Elevation (Feet)	Angle Below Horizon (degrees)	Antenna Vertical Pattern (dB)	Distance From Antenna (Feet)	Channels Power Density (uW/cm^2)	% of Revised ANSI Standard (590uW/cm^2)	Comments:
0	0	90.0	-29.0	29.0	1.669	0.2829%	
5	0	80.2	-29.0	29.4	1.621	0.2747%	
10	0	71.0	-26.0	30.7	2.976	0.5044%	
20	0	55.4	-17.0	35.2	17.924	3.0380%	
30	10	32.3	-11.5	35.5	62.588	10.6081%	2nd floor of adj apartment
40	0	35.9	-10.8	49.4	38.427	6.5131%	1st floor of adj apartment
50	0	30.1	-12.5	57.8	18.764	3.1804%	
60	0	25.8	-19.0	66.6	3.160	0.5356%	
70	0	22.5	-12.3	75.8	11.435	1.9381%	
80	0	19.9	-9.0	85.1	19.382	3.2851%	
90	0	17.9	-7.0	94.6	24.878	4.2167%	
100	0	16.2	-6.1	104.1	25.535	4.3280%	
110	0	14.8	-4.6	113.8	30.566	5.1807%	
120	0	13.6	-3.9	123.5	29.798	5.0506%	
130	0	12.6	-3.1	133.2	31.133	5.2769%	
140	0	11.7	-2.5	143.0	30.669	5.1982%	
150	0	10.9	-2.0	152.8	30.136	5.1078%	
160	0	10.3	-2.0	162.6	26.603	4.5090%	
170	0	9.7	-1.8	172.5	25.062	4.2482%	
180	0	9.2	-1.8	182.3	22.416	3.7991%	
190	0	8.7	-1.3	192.2	22.372	3.7918%	
200	0	8.3	-1.3	202.1	20.235	3.4297%	
225	0	7.3	-0.9	226.9	17.607	2.9842%	
250	0	6.6	-0.8	251.7	14.639	2.4812%	
275	0	6.0	-0.8	276.5	12.127	2.0553%	
300	0	5.5	-0.3	301.4	11.453	1.9412%	
325	0	5.1	-0.3	326.3	9.772	1.6563%	
350	0	4.7	-0.1	351.2	8.833	1.4971%	
375	0	4.4	-0.1	376.1	7.701	1.3053%	
400	0	4.1	-0.1	401.0	6.773	1.1480%	
450	0	3.7	0.0	450.9	5.463	0.9282%	
500	0	3.3	0.0	500.8	4.444	0.7533%	
600	0	2.8	0.0	600.7	3.090	0.5236%	
700	0	2.4	0.0	700.6	2.271	0.3850%	
800	0	2.1	0.0	800.5	1.740	0.2949%	
900	0	1.8	0.0	900.5	1.375	0.2330%	
1000	0	1.7	0.0	1000.4	1.114	0.1888%	
1500	0	1.1	0.0	1500.3	0.495	0.0839%	
2000	0	0.8	0.0	2000.2	0.279	0.0472%	
2500	0	0.7	0.0	2500.2	0.178	0.0302%	
3000	0	0.6	0.0	3000.1	0.124	0.0210%	
4000	0	0.4	0.0	4000.1	0.070	0.0118%	
5000	0	0.3	0.0	5000.1	0.046	0.0078%	

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Assumptions:

1.) "B-Band" Cellular Transmitter Frequencies are 880.02 to 893.85 MHz.

2.) All exposures will be in the far-field region since the longest wavelength is 14 inches.

3.) Exposures include 64% reflected energy from the ground.

4.) Calculations are worst case based on theoretical antennas that provide maximum gain for 360 degrees in the horizontal plane.

Cellular Power Density for the Ravenna Cell Site.

Prepared by: Roy Norgaard 09/22/94

Antenna Height:	38 feet	ERP/Chan.	50 watts
Measurement Ht.	6 feet	Antenna:	DB 833R
Number of Radio Chan	30		

Distance From Tower (Feet)	Adjusted Vertical Elevation (Feet)	Angle Below Horizon (degrees)	Antenna Vertical Pattern (dB)	Distance From Antenna (Feet)	Channels Power Density (uW/cm^2)	% of Revised ANSI Standard (590uW/cm^2)	Comments:
0	0	90.0	-29.0	32.0	0.685	0.1162%	
5	0	81.1	-29.0	32.4	0.669	0.1134%	
10	0	72.6	-28.0	33.5	0.786	0.1332%	
20	0	58.0	-17.5	37.7	6.961	1.1798%	
30	0	46.8	-13.1	43.9	14.190	2.4050%	
40	0	38.7	-10.6	51.2	18.502	3.1359%	
50	0	32.6	-11.5	59.4	11.198	1.8980%	
60	0	28.1	-14.0	68.0	4.799	0.8134%	
70	0	24.6	-17.0	77.0	1.877	0.3182%	
80	0	21.8	-11.1	86.2	5.828	0.9878%	
90	0	19.6	-9.0	95.5	7.691	1.3036%	
100	0	17.7	-7.0	105.0	10.089	1.7100%	
110	0	16.2	-6.1	114.6	10.547	1.7875%	
120	20	5.7	-0.3	130.8	30.414	5.1550%	3rd floor apt to north
130	0	13.8	-3.9	133.9	12.669	2.1473%	30
140	0	12.9	-3.1	143.6	13.391	2.2696%	
150	0	12.0	-3.1	153.4	11.740	1.9898%	
160	0	11.3	-2.5	163.2	11.773	1.9955%	
170	0	10.7	-2.0	173.0	11.753	1.9921%	
180	0	10.1	-2.0	182.8	10.522	1.7835%	
190	0	9.6	-1.8	192.7	10.035	1.7009%	
200	0	9.1	-1.8	202.5	9.081	1.5392%	
225	0	8.1	-1.3	227.3	8.000	1.3560%	
250	0	7.3	-0.9	252.0	7.132	1.2089%	
275	0	6.6	-0.8	276.9	6.049	1.0252%	
300	0	6.1	-0.8	301.7	5.094	0.8633%	
325	10	3.9	0.0	327.7	5.191	0.8798%	Typical 2 story residence
350	0	5.2	-0.3	351.5	4.211	0.7138%	
375	0	4.9	-0.1	376.4	3.846	0.6518%	
400	0	4.6	-0.1	401.3	3.383	0.5734%	
450	0	4.1	-0.1	451.1	2.676	0.4536%	
500	0	3.7	0.0	501.0	2.221	0.3764%	
600	0	3.1	0.0	600.9	1.544	0.2617%	
700	0	2.6	0.0	700.7	1.135	0.1924%	
800	0	2.3	0.0	800.6	0.870	0.1474%	
900	0	2.0	0.0	900.6	0.687	0.1165%	
1000	0	1.8	0.0	1000.5	0.557	0.0944%	
1500	0	1.2	0.0	1500.3	0.248	0.0420%	
2000	0	0.9	0.0	2000.3	0.139	0.0236%	
2500	0	0.7	0.0	2500.2	0.089	0.0151%	
3000	0	0.6	0.0	3000.2	0.062	0.0105%	
4000	0	0.5	0.0	4000.1	0.035	0.0059%	
5000	0	0.4	0.0	5000.1	0.022	0.0038%	

Assumptions:

1.) "B-Band" Cellular Transmitter Frequencies are 880.02 to 893.85 MHz.

2.) All exposures will be in the far-field region since the longest wavelength is 14 inches.

3.) Exposures include 64% reflected energy from the ground.

4.) Calculations are worst case based on theoretical antennas that provide maximum gain for 360 degrees in the horizontal plane.

Cellular Power Density for the Laurelhurst Cell Site.

Prepared by Roy Norgaard

11/07/94

Antenna Height:	45	feet	ERP/Chan:	100 watts
Measurement Ht:	5	feet	Antenna:	DB 833R
Number of Radio Chr	30			

Distance From Tower (Feet)	Adjusted Vertical Elevation (Feet)	Angle Below Horizon (degrees)	Antenna Vertical Pattern (dB)	Distance From Antenna (Feet)	Channels Power Density (uW/cm^2)	% of Revised ANSI Standard (590uW/cm^2)	Comments:
0	0	90.0	-29.0	39.0	0.923	0.1564%	
5	0	82.7	-29.0	39.3	0.908	0.1539%	
10	0	75.8	-28.9	40.3	1.420	0.2408%	
20	0	62.9	-20.1	43.8	5.671	0.9612%	
30	0	52.4	-15.3	49.2	~~13.590~~	2.3033%	
40	0	44.3	-12.2	55.9	21.523	3.6480%	stores along Sand Point Way
50	0	38.0	-10.7	63.4	23.871	4.0459%	stores along Sand Point Way
60	0	33.0	-11.1	71.6	~~16.898~~	2.8642%	
70	0	29.1	-13.8	80.1	7.238	1.2267%	
80	0	26.0	-19.0	89.0	1.772	0.3003%	
90	0	23.4	-14.0	98.1	4.613	0.7819%	
100	0	21.3	-11.1	107.3	7.511	1.2731%	
110	0	19.5	-9.0	116.7	10.304	1.7464%	
120	0	18.0	-8.0	126.2	11.098	1.8810%	
130	0	16.7	-6.1	135.7	15.028	2.5471%	
140	0	15.6	-5.2	145.3	15.940	2.7017%	
150	0	14.6	-4.5	155.0	16.467	2.7910%	
160	0	13.7	-3.9	164.7	16.746	2.8382%	
170	0	12.9	-3.1	174.4	18.15[illegible]	3.0774%	Thriftway parking lot
180	0	12.2	-3.1	184.2	16.283	2.7598%	
190	0	11.6	-2.5	194.0	16.664	2.8244%	
200	0	11.0	-2.5	203.8	15.099	2.5591%	
225	0	9.8	-1.8	228.4	14.288	2.4218%	
250	0	8.9	-1.3	253.0	12.909	2.1879%	
275	0	8.1	-1.3	277.8	10.713	1.8167%	
300	0	7.4	-0.9	302.5	9.901	1.6782%	
325	0	6.8	-0.8	327.3	8.654	1.4668%	
350	0	6.4	-0.8	352.2	7.477	1.2672%	
375	0	5.9	-0.3	377.0	7.319	1.2406%	
400	0	5.6	-0.3	401.0	6.441	1.0918%	
450	0	5.0	-0.1	451.7	5.340	0.9051%	
500	0	4.5	-0.1	501.6	4.331	0.7341%	
600	0	3.7	0.0	601.3	3.084	0.5227%	
700	0	3.2	0.0	701.1	2.268	0.3844%	
800	0	2.8	0.0	801.0	1.738	0.2946%	
900	0	2.5	0.0	900.8	1.374	0.2328%	
1000	0	2.2	0.0	1000.8	1.113	0.1887%	
1500	0	1.6	0.0	1500.6	0.405	0.0839%	
2000	0	1.1	0.0	2000.4	0.279	0.0472%	
2500	0	0.9	0.0	2500.3	0.178	0.0302%	
3000	0	0.7	0.0	3000.3	0.124	0.0210%	
4000	0	0.6	0.0	4000.2	0.070	0.0118%	
5000	0	0.4	0.0	5000.2	0.046	0.0078%	

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Assumptions:

1.) "B-Band" Cellular Transmitter Frequencies are 880.02 to 893.85 MHz.

2.) All exposures will be in the far-field region since the longest wavelength is 14 inches.

3.) Exposures include 64% reflected energy from the ground

4.) Calculations are worst case based on theoretical antennas that provide maximum gain for 360 degrees in the horizontal plane

EPA-600/8-83-026F
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Biological Effects of Radiofrequency Radiation

Edited by

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Seattle WA residents get 4 fold to 12 fold MORE
Moscow Embassy

Table 5-30. Microwave Exposure Levels at the U.S. Embassy in Moscow*

Time Period	Exposed Area of Chancery	Power Density and Exposure Duration
1953 to May 1975	West Facade	Max of 5 μW/cm², 9 h/day
June 1975 to Feb 1976	South and East Facade	18 μW/cm², 18 h/day
Since Feb 7 1976	South and East Facade	Fractions of a μW/cm², 18 h/day

*Data from Lilienfeld *et al* 1978

Extensive efforts were launched to identify and trace the populations. Information on illnesses, conditions, or symptoms were sought from two major sources: (1) employment medical records, which were fairly extensive, given examination requirements for foreign duty, and (2) a self-administered health history questionnaire. Questionnaire responses were validated for a stratified sample by review of hospital, physician, and clinic records. Death certificates were also sought, although other sources also were used to ascertain mortality status.

Standardized mortality ratios for various subgroups were calculated for each cause of death, were standardized for age and calendar period, and were specific for sex. Similar procedures were used to develop summary indices of morbidity.

A total of 4388 employees and 8283 dependents were studied. More than 1800 with 3000 dependents were employed at the Moscow Embassy and 2500 with more than 5000 dependents worked at the comparison posts. Ninety-five percent of the employees were traced. Receipt of completed questionnaires was less successful, with an overall response rate of 52 percent for State Department personnel.

Based on information in medical records, various health problems were generally similar, with two exceptions. Moscow employees had a threefold greater risk of acquiring protozoal infections than comparison-post employees. In general, both sexes in the Moscow group had somewhat higher frequencies of most of the common kinds of health conditions reported. Lilienfeld *et al.* (1978) stated, "However, these most common conditions represented a very heterogeneous collection and it is difficult to conclude that they could have been related to exposure to microwave radiation since no consistent pattern of increased frequency in the exposed group could be found."

Some excesses were reported by Moscow employees in the health history questionnaire. Both sexes reported more eye problems due to correctable refractive errors. More psoriasis was reported by men and anemia by women. The Moscow employees, especially males, reported more symptoms such as irritability, depression, difficulties in concentration, and loss of memory. It is possible, however, that a bias due to awareness of potential adverse effects is operating, since the strongest differences were present in the subgroup with the least exposure.

Symptoms Soviets associate with MICROWAVES

The observed mortality was less in both male and female employees than expected, based on U.S. mortality rates; the male employees had more favorable experience than female employees. In both sexes, cancer was the predominant cause of death. The Moscow and comparison groups did not differ appreciably in overall and specific mortality. However, the population was relatively young; it may have been too early to detect long-term mortality effects. But since Goldsmith Stu

The authors concluded that no convincing evidence was discovered to implicate microwaves in the development of adverse health effects at the time of the analysis. But they also carefully discussed the limitations inherent in the study: uncertainties associated with the reconstruction of the employee populations and dependents, difficulties of obtaining death certificates, the low percentage of responses for the questionnaire, and the statistical power of the study. The limitation most critical for consideration in a document such as this relates to ascertainment of exposure. Problems relative to individual mobility within the embassy and variation of field intensities within the building are present in this study as in any other. No records were available on where employees lived or worked, so one had to rely on questionnaire responses to estimate an individual's potential for exposure. The highest exposure level (18 μW/cm²) was recorded for only 6 months in 1975-76; thus, the group exposed to the most intense fields had the shortest cumulative time of exposure and of observation in the study.

Robinette and Silverman (1977) and Robinette *et al.* (1980) examined mortality and morbidity among U.S. naval personnel occupationally exposed to radar. Records of service technical schools were used to select subjects for the study; the men graduated from technical schools during the period from 1950 through 1954. Exposure categorizations were made on the basis of occupational specialty. The exposure group (probably highly exposed) consisted of technicians involved in repair and maintenance of radar equipment. The controls (probably minimally exposed) were involved in the operation of radar or radio equipment. It was estimated from shipboard monitoring that radiomen and radar operators (in the low-exposure group) were generally exposed at less than 1 mW/cm², and gunfire control and electronics technicians (in the high-exposure group) were exposed to higher levels during their duties. Over 40,000 veterans were included in the study, with about equal numbers in these two major exposure classifications. The mean age in 1952 of the low-exposure group was 20.7 years and of the high-exposure group, 22.1 years. In conjunction with naval

Dr John R. Goldsmith, Professor of Epidemiology, faculty of Health Sciences, Ben-Gurion University of Negev, Israel, is an eminent and internationally recognised and respected epidemiologist who has told me personally that he had no trouble at all with his reviewers nor the editor in getting this paper published.

I have studied several of Dr Goldsmith's references which are published in journals which are held by the Medical School Library in Christchurch and Dr Goldsmith's paper fairly represents the findings of these papers.

For example, the study of miscarriages among female physiotherapists in the United States.

Regarding U.S. Moscow Embassy staff + dependents

Dr Goldsmith carried out his own review of all published documents surrounding the U.S. Moscow embassy exposure, including significant material obtained under the Official Information Act and not previously published. Dr Goldsmith points out, as other researchers have concluded also, that concentration on death as an outcome, ignores a host of evidence of changed health status which is statistically correlated to increased exposure to microwaves.

It was found that despite the lower than average age of the embassy staff and families than the general U.S. population, there was a statistically significant increase with white cell counts, mean hematocrit increased and a threefold increase in monocyte count, while neutrophil percentage fell and then rose and the reverse occurred for lymphocytes. There were raised cancer deaths (15 out of 31 women staff), including leukemia, female genitalia cancer and child cancer.

Adult dependents showed five malignant neoplasms compared with 1.5 expected and dependent children showed greater than expected anemia.

In the Moscow embassy case the mean exposure levels are estimated at between 5μW/cm^2 and 18μW/cm^2, compared to the "safe level" of the New Zealand standard of 200 μW/cm^2. Assuming an average 40 hour working week, the mean exposure of embassy staff is in the range 1 μW/cm^2 to 4 μW/cm^2.

In his discussion Dr Goldsmith makes the following observation which is significant from a person of his standing, but is shared by every researcher of the five I have contacted so far:

> "There are strong political and economic reasons for wanting there to be no health effect of RF/MW (radiofrequency/microwave) exposure, just as there are strong public health reasons for more accurately portraying the risks. Those of us who intend to speak for public health must be ready for opposition that is nominally but not truly, scientific."

8.5 Chinese research:

Totally separate and independent of Dr Goldsmith's work there are several other researchers and research groups who have detected significant changes in health status in workers exposed to microwaves. The following abstract appears among those from the Second Annual Meeting of the International Society for Environmental Epidemiology, Berkeley, California, August 13-15, 1990. Judging by the terminology and the author's name this is presumed at this stage to be based on work in China. Work is going on in China which has been reported in Microwave News.

from review By Dr. Neil Cherry

Paul Brodeur

W · W · Norton & Company · Inc ·
New York

The Zapping of America

Microwaves, Their Deadly Risk, and the Cover-Up

1977

about anything. President Carter had recently criticized their failure to observe basic human rights, and the State Department had claimed that the Moscow drinking water contained dangerous amounts of cyanide and mercury. According to Wren, the Soviet health officials did see fit to present a basic textbook on hematology to Dr. Stossel—a gesture some diplomats considered condescending. Whether this gesture was an attempt to condescend or to educate is a matter of opinion, especially in light of what two members of the State Department's medical team were quoted as saying during their Moscow visit. Dr. Watson, for example, reported that the lymphocyte counts, which ran forty-four percent above normal in 64 out of 213 American diplomats and their dependents who were tested, constituted a "slight shift." And Dr. Stossel declared that the abnormality, which receded after the Americans left Moscow, "has no known pathological meaning."

The certainty of these two medical doctors about the abnormal lymphocyte counts may well have temporarily reassured the Americans who live and work at the Moscow Embassy. During the early part of May 1977, however, an article written by Keyes Beech, a syndicated *Chicago Daily News* columnist, appeared in newspapers around the country. One version began as follows:

> The State Dept. has given Johns Hopkins University of Baltimore a $250,000 contract to determine whether there is a link between microwave radiation beamed at the U.S. embassy in Moscow and an apparently high rate of cancer among Americans serving there.
>
> Richard Moose, deputy undersecretary of state for management, said the cost of the research project might go as high as $400,000 before it is completed and that it would be a year or more before the results are known.
>
> "But it will be worth it to lower the anxiety level among Moscow Embassy personnel and restore credibility in the State Dept. management by Foreign Service families who felt they have been victimized," said Moose, who visited Moscow six weeks ago.
>
> A separate, nonscientific study is being conducted by an emotionally involved Foreign Service officer whose wife developed breast cancer while they were serving in Moscow, Moose said.
>
> The survey has disclosed that 16 American women who served in Moscow developed breast cancer, Moose said. Two former American ambassadors to Moscow, Charles (Chip) Bohlen and Llewellyn Thompson, both died of cancer in the past few years.
>
> Zbigniew Brzezinski, Polish-born national security adviser to President Carter, told this reporter in March 1976, in Tokyo, that the cancer rate among Americans in the Moscow embassy was the highest in the world.
>
> He blamed Soviet microwave radiation beamed at the embassy for what appears to be the abnormally high cancer rate.
>
> "But none of this proves anything," Moose said. "We just don't know, but we are determined to find out."
>
> Dr. E. Cuyler Hammond of the American Cancer Society scoffed at the idea that microwaves can cause cancer.
>
> "This is poppycock Buck Rogers stuff," he snorted. "The chances are just about nil, although not impossible. Microwaves are not like gamma rays or X-rays which do penetrate the cells and cause cancer."
>
> Dr. James M. Sontag of the National Cancer Institute at Bethesda, Md., was more cautious. "I wouldn't scoff at the possibility," he said. "It's true that microwaves are non-ionizing and therefore supposedly not carcinogenic.
>
> "But ultra-violet light is also non-ionizing and it can cause cancer," he said. "That's the way people get skin cancer."

Considering all the evidence, Dr. Sontag's remarks about a possible link between microwave irradiation and cancer seem eminently sensible; those voiced by Dr. Hammond do not. Dr. Hammond is Vice-President for Epidemiology and Statistics of the American Cancer Society; he participated in an analysis of the medical effects of the atomic explosions that devastated Hiroshima and Nagasaki in 1945; his large-scale epidemiological studies of more than a million men and women provided a major basis for the conclusions drawn in the 1964 Surgeon General's report on the health effects of cigarette smoking; his statistical analysis of mortality among asbestos workers has provided a major basis for the certainty that asbestos inhalation is cancer-producing; and he, more than most people, should know better than to dismiss out of hand something he has not even bothered to study. One wonders if Dr. Hammond would dismiss as "poppycock Buck Rogers stuff" a suggestion that microwave radiation affects the central nervous system and alters behavior, or that it may cause genetic damage. And what would he say to the fact that when the State Department secretly tested young women from the Moscow Embassy for genetic damage during the late 1960s, it found evidence that such damage had occurred?

Shows example of where Lower Power has an effect when a higher power does NOT.

Paff *et al.* (1963), working with the isolated embryonic chicken heart, were unable to detect changes in heart rate during exposure to 24,000-MHz (PW) radar fields. They did, however, detect effects on the electrocardiogram (ECG), including abnormal P and T waves from 3-min exposures at 74 mW/cm².

Frey and Seifert (1968) showed that 10-μs pulses at a carrier frequency of 1.425 GHz given at a synchronous period with the ECG (220 ms after the P wave) resulted in tachycardia or heart arrhythmia in the isolated frog heart. The peak power density was 60 mW/cm² (average power density ~0.6 μW/cm²). Liu *et al.* (1976) reported no effect on heart rate with isolated frog hearts or in hearts irradiated *in situ* in a similar study. The *in situ* hearts were exposed to 100-μs pulses of either 1.42 or 10 GHz, and the isolated frog hearts were exposed to 100-μs pulses of 1.42 GHz. The pulse was delivered on the rising phase of the R-wave from the ECG, which as somewhat similar to, but not exactly the same as, the 200-ms delay following the P-wave used by Frey and Seifert. (The R-wave follows the P-wave by about 200 ms.) The peak and average power densites of 320 mW and 32 μW were also considerably higher than those used by Frey and Seifert. These factors, plus differences in the manner of preparing the isolated hearts (Liu *et al.* curarized the frogs, whereas Frey and Seifert decapitated the frogs), make it difficult to compare the results of the two studies.

Clapman and Cain (1975), however, tried to replicate the study of Frey and Seifert using similar pulse widths (10 μs), peak and average power densities (60 mW/cm² and 0.6 μW/cm²), carrier frequency (1.42 GHz), and method of isolating the frog heart; they reported no change in heart rate. Also, no heart rate changes were found when they conducted studies with a different peak power (5.5 W/cm²), frequency (3 GHz), and pulse widths (2 and 150 μs). Clapman and Cain were able to produce an increased heart rate with 20-mA current pulses synchronized 200 ms after the P-wave peak.

The results of microwave exposure on the cardiovascular system (Table 5-22) indicate that whole-body exposure of sufficient intensity to produce heating also produces an increase in heart rate similar to that which would be expected from heating alone. In the isolated heart there appears to be a stimulation of the autonomic nervous system from microwave exposure at levels where very little heating would be expected (1 to 2 W/kg). Low levels of synchronized PW microwaves (0.6 to 32 mW/kg) apparently are ineffective in producing detectable alterations in heart rate.

5.7.5 Biological Effects of Low Frequency Modulation of RF Radiation

Interest in the biological effects of low frequency modulation of RF radiation stems from reports of changes caused by exposure to electric and magnetic fields in the sub-ELF range (0 to 30 Hz). It has been reported that exposure to low-frequency electric fields changes the reaction time in humans (Konig and Ankermuller 1960; Hamer 1968; Konig 1971) and in monkeys (Gavalas; *et al.* 1970; Gavalas-Medici and Day-Magdaleno 1976), and alters circadian activity in human beings (Wever 1973). Friedman *et al.* (1967) observed that magnetic fields modulated at low frequencies also change reaction time in human beings.

Two other studies that provide important background information are reported by Kaczmarek and Adey (1973, 1974). In the first report, they described release of calcium ions and γ-aminobutyric acid (GABA) from the cerebral cortex of cats in response to small changes in the extracellular concentration of calcium. In 1974, they demonstrated release of calcium ions and GABA from the cat cortex in response to low intensity electric currents, pulsed at 200 Hz, applied directly to the cerebral cortex. Thus, extracellular calcium and electric current have similar effects on the release of GABA and calcium ions from brain tissue.

The studies of (1) behavioral changes in animals and human beings induced by low frequency signals and (2) biochemical changes in the cat brain caused by electric currents led to a study of the influence of electric fields on EEG patterns associated with a conditioned behavioral response in cats (Bawin *et al.* 1973). To increase the penetration of the signals into the tissue, they chose an RF carrier wave of 147 MHz, which was amplitude modulated at sub-ELF frequencies (e.g., 3 to 14 Hz). Alterations were observed in the rate of performance, accuracy of reinforced patterns, and resistance to extinction in learned behavior of the exposed animals compared to controls, indicating that the fields were acting as reinforcers. In order to determine whether these effects were mediated via peripheral receptors or occurred as a result of changes induced directly on the CNS, experiments were designed to examine the effects of modulated RF carrier waves on brain tissue *in vitro*.

5.7.5.1 Calcium Ion Efflux *In Vitro:* A Fundamental Finding

The association of calcium ions with brain tissue was selected as the biochemical marker to examine the influence of modulated RF fields because calcium ion efflux has been shown to be sensitive to electric currents applied directly to brain tissue *in vitro*, and because calcium ions have a prominent role in many biochemical and biophysical processes (e.g., cellular membrane integrity and function, enzyme cofactor, putative second messenger for the conduction of extracellular signals to the nucleus of the cell, neural tissue excitation and secretion of transmitter

Thus because there was not a dose response effect at Moscow substances at synapses). The first report of the influence of modulated RF fields on excised brain tissue was Bawin *et al.* (1975), who showed that a 20-min exposure of chick brain tissue *in vitro* to a 147-MHz field at 1 to 2 mW/cm^2 (SAR estimated at 0.002 W/kg) caused enhanced efflux of calcium ions, but only if the field was sinusoidally amplitude modulated at frequencies of 6, 9, 11, 16, or 20 Hz. Maximal efflux was measured at 16 Hz. Modulation frequencies of 0, 0.5, 3, 25, and 35 Hz were ineffective. This frequency-specific response, which occurred while the 147-MHz carrier field was maintained at the same power density, indicates that the field-induced efflux of calcium ions was not due to heating of the samples.

In another report, Bawin *et al.* (1978) exposed chick brain tissue for 20 min to 450-MHz fields, amplitude modulated at 16 Hz, at 0.75 mW/cm^2 (SAR estimated at 0.0035 W/kg) under a variety of chemical conditions. The results demonstrated that (a) the enhanced efflux of calcium ions is not highly sensitive to the external calcium concentration, (b) bicarbonate appears to be important for enhanced efflux, (c) lowering the pH from 7.6 to 6.8 in the presence of bicarbonate may enhance the magnitude of efflux, and (d) lanthanum causes a reversal to field-induced retardation of calcium ion efflux.

Corroboration of the frequency-specific response described by Bawin and co-workers was provided by Blackman *et al.* (1979), who showed that 16-Hz amplitude modulation of 147-MHz carrier waves caused enhanced efflux in chick brain tissue *in vitro*, whereas modulation frequencies of 3, 9, and 30 Hz did not. Although the data had large variances, an unusual intensity response was described, i.e., only 0.83 mW/cm^2 (SAR estimated at 0.0014 W/kg) produced a statistically significant efflux enhancement (intensity values are corrected based on discussion in Blackman *et al.* 1980a); power densities (0.11, 0.55, 1.11 and 1.38 mW/cm^2) below and above the effective value did not cause efflux. In a later report, Blackman *et al.* (1980a) used a revised statistical model and experimental procedure to reduce the influence of the large sample variance. An intensity response identical to their earlier result was found. However, when the distance between samples was halved, the range of intensities that produced enhanced efflux increased to include 0.55, 0.83, 1.11 and 1.38 mW/cm^2, whereas lower and higher values of 0.11 and 1.66 mW/cm^2 were ineffective. In addition, an intensity region from 0.55 to 1.11 mW/cm^2 caused enhanced efflux when 9 Hz was used as the modulation frequency. These data, obtained with a more rigorous experimental protocol, provided additional support for the results of Bawin *et al.* (1975) and Blackman *et al.* (1979); however, the explanation for the dependence on sample spacing awaited further developments.

Joines *et al.* (1981) examined the dependence on sample spacing by calculation of the electrical coupling between the samples; for similicity the samples were modeled as spheres. They found that increased electrical interaction between the more closely packed spheres produced a broader range of internal field strengths within each sphere. Thus, if a given internal field strength were necessary to cause enhanced efflux, the chance would be greater for that internal field strength to occur in closely coupled samples exposed to a specific range of incident intensities. Joines *et al.* (1981) found this result to be consistent with the experimental findings in Blackman *et al.* (1980a). Thus a potential artifact was shown to be a logical result of the experimental procedures.

The intensity response observed by Blackman *et al.* (1979) with modulated 147-MHz carrier waves was confirmed by Sheppard *et al.* (1979) with 450-MHz carrier waves, modulated at 16 Hz; calcium-ion efflux was enhanced at 0.1 and 1.0 mW/cm^2 but not at 0.05, 2.0, or 5.0 mW/cm^2. (The estimated SAR at 1.0 mW/cm^2 is 0.0047 W/kg.) The results of these two reports show that the intensities producing calcium-ion efflux from chick brain tissue *in vitro* are within the range of 0.1 to 1.38 mW/cm^2 for modulated 147-MHz and 450-MHz carrier waves.

The apparent carrier-frequency independence of effective intensities was tested with a 50-MHz carrier wave, amplitude modulated at 16 Hz. Enhanced efflux of calcium ions occurred within two intensity regions (between 1.44 and 1.67, and at 3.64 mW/cm^2; SARs were 0.0013 and 0.0035 W/kg, respectively) separated by intensities of no effect, including 0.72 mW/cm^2 (Blackman *et al.* 1980b). These effective intensity values were different from the corresponding values of 147-MHz radiation; thereby indicating a dependence on carrier frequency. In addition this result revealed the existence of more than one range of effective intensities.

The apparent discrepancy in effective power densities at the three different carrier frequencies (50, 147, and 450 MHz) has been resolved by the finding that efflux is dependent on the electric field strength within the tissue and not on incident intensity (Joines and Blackman 1980). The calculation to transform the incident intensity to internal field strength was based on an empirical model described by Joines *et al.* (1981). With the data available at 50 and 147 MHz, the model was used to predict intensities that would produce both alterations and no alterations in calcium-ion efflux; some predictions were tested and found to be valid (Blackman *et al.* 1981). These reports described two intensity ranges that appear effective for enhanced efflux at both 50 and 147 MHz, identified the internal electric field strength rather than incident intensity as the important exposure parameter, and showed the

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Subsequent to the critique by Athey (1981) that the simple spherical model used by Joines and Blackman (1980) was too idealized, these authors showed that a layered sphere model produced relationships between incident intensities at 50, 147, and 450 MHz and internal field strengths that were also consistent with the experimental results (Joines and Blackman 1981). The success of the initial, simple models to predict intensity regions of both field-induced efflux enhancement and no enhancement demonstrates the utility of the approach. More refinements in the models are necessary before the experimental situation is realistically described.

Shelton and Merritt (1981), who used different procedures from those described by Bawin *et al.* (1975), Blackman *et al.* (1979, 1980a,b), and Sheppard *et al.* (1979) reported no change in calcium-ion efflux from rat brain. Brain tissue, labeled *in vitro* with radioactive calcium, was irradiated at 1 GHz, pulse-modulated with square waves at 16 or 32 Hz (0.5, 1.0, 2.0, and 15 mW/cm²). In a second report, Merritt *et al.* (1982) exposed rat brain tissue labeled *in vivo* with radioactive calcium to microwave radiation, pulse modulated at 16 Hz (20-ms pulse width). The intensities for the 1-GHz carrier frequency were 1 mW/cm² (SAR = 0.29 W/kg) and 10 mW/cm² (SAR = 2.9 W/kg); and for the 2.45-GHz carrier frequency, 1 mW/cm² (SAR = 0.3 W/kg). In addition, animals labeled with radioactive calcium were exposed for 20 min to 2.06-GHz radiation at one of 17 different combinations of intensity and pulse repetition rate: 0, 0.5, 1.0, 5.0, 10.0 mW/cm² (SAR was 0.24 W/kg per mW/cm²); and 0, 8, 16, 32 Hz (pulse width was 10 ms). After exposure, brain tissue was analyzed for radioactivity. No statistically significant field-induced enhancement of calcium-ion efflux or change of calcium content in the brain tissue was found. The reason for these negative findings is not known; however, the use of square wave rather than sine wave modulation, the different biological preparation, and different medium composition are factors that may have influenced the outcome.

5.7.5.2 Additional CNS Studies

The reports of field-induced calcium-ion efflux from chick brain tissue *in vitro* have led to other CNS studies. Synaptosomes, prepared from rat cerebra and labelled with radioactive calcium, were exposed for 10 min at 0.5 mW/cm² to 450-MHz fields, amplitude modulated at 0, 16, or 60 Hz (Lin-Liu and Adey 1982). Only 16 Hz affected the efflux kinetics of calcium ions. Although the SAR can be estimated as low, an exact value cannot be unequivocally established because the exposure chamber may have been operated in a multimodal condition. (See Weil *et al.* 1981.) Nevertheless, this result is modulation dependent, and it is unlikely that heating is involved as a causative agent.

Similar field-induced efflux enhancement has been reported in a live animal. Adey *et al.* (1982) exposed awake, immobilized cats to 450-MHz fields, amplitude modulated at 16 Hz, at 3.0 mW/cm² (SAR = 0.29 W/kg). The release of calcium ions from the cortex was observed as a function of time. Irradiation for 60 min caused episodes of enhanced efflux lasting 20 to 30 min and extending into the postexposure period. Although focusing on a different component of the efflux kinetics than that studied by Lin-Liu and Adey (1982), these results demonstrate that RF fields modulated at 16 Hz can cause changes in both a subcellular membrane system and in the live mammal. Thus, the field-induced phenomenon is not restricted to an avian species nor to *in vitro* preparations.

Recently, Dutta *et al.* (1984) observed field-induced enhancement of calcium ions from cells of human origin. Monolayer cultures of human neuroblastoma cells were exposed for 30 min at ten SARs from 0.01 to 5.0 W/kg to 915-MHz fields, with or without sinusoidal amplitude modulation (80 percent) at frequencies between 3 and 30 Hz. Significant increases in the efflux of calcium ions occurred at two SARs (0.05 and 1.0 W/kg). The increased efflux at 0.05 W/kg was dependent on the presence of 16-Hz modulation but not at the higher value. Exposure at modulation frequencies between 3 and 30 Hz (SAR = 0.05 W/kg) revealed a peak in the response at 16 Hz. Although the effective SAR (0.05 W/kg) for 16-Hz modulation is more than 38 times greater than the SARs for enhanced efflux of calcium ions from chick brain tissue *in vitro*, the low-frequency response pattern was similar to that reported by Bawin *et al.* (1975) and Blackman *et al.* (1979). The relation of enhanced efflux with unmodulated fields at 1.0 W/kg with the effects of modulated fields is not known at this time; however, it is not due to a temperature increase in the sample because enhancement was not found at SARs of 2.0 and 5.0 W/kg.

The effect of modulated RF fields on the EEG was investigated by Takashima *et al.* (1979). Rabbits were exposed 2 h daily for 6 weeks to 1.2 MHz, amplitude modulated at 15 Hz, or 5 MHz amplitude modulated at 14 Hz. Following exposure, the EEG was recorded with scalp electrodes and, when compared to the pretreatment EEG pattern, was found to be altered with enhanced low-frequency components and decreased high-frequency components. The EEG pattern returned to the pretreatment pattern after several weeks postexposure. Although the electric field intensity was given as 500 V/m, with an error factor as large as 2, the important aspect of the results was that unmodulated fields of similar intensity had no effect on the EEG pattern. The absence of metallic electrodes in the animal during exposure avoids the major criticism of earlier studies that reported field-induced changes in EEG patterns (Gavalas *et al.* 1970; Bawin *et al.* 1973).

Sagan and Medici (1979) studied the influence of 450-MHz fields, sinusoidally amplitude modulated at either 3 or 16 Hz, on locomotor activity in young chickens. The experiments were performed in a plastic, modified Skinner box with light beams to monitor activity; the complete apparatus was placed in an anechoic chamber and exposed in the far field. The authors found no statistically significant change in performance during or immediately after a 23-min exposure at 1 or 5 mW/cm^2 (SAR estimated at 0.2 and 1.0 W/kg). They concluded that the lack of a field-induced response could be due to the use of modulation frequencies not present in the chicken's EEG during performance on the particular (fixed-time schedule) task. An alternative possibility, based on the multiple-intensity ranges observed for field-induced calcium-ion efflux, is that the two intensities used in this study may have been outside the effective ranges.

In summary, four groups (Adey *et al.*; Blackman *et al.*; Dutta *et al.*; Takashima *et al.*) have shown that RF fields, sinusoidally modulated at sub-ELF frequencies, especially 16 Hz, cause CNS changes in different *in vitro* preparations and in the live animal. Many of these studies have been analyzed in reviews (Adey 1981; Blackman *et al.* 1981; Greengard *et al.* 1982; Myers and Ross 1981). It is generally agreed that both the mechanism of interaction and the physiological consequences of these changes are yet to be established.

5.7.5.3 Non-CNS Studies

The effects of exposure of pancreatic tissue and T-lymphocytes to RF fields, sinusoidally amplitude modulated at low frequencies, have been examined. An increase of calcium-ion efflux from rat pancreatic tissue exposed *in vitro* at 2 mW/cm^2 for 1 to 2.5 h at 147 MHz, modulated at 16 Hz (estimated SAR $<$ 0.075 W/kg), has been reported by Albert *et al.* (1980). However, the efflux was not accompanied by a change in protein secretion, which is normally associated with calcium mobilization in the pancreas. The authors attributed the lack of protein secretion to a limitation imposed by the exposure conditions, i.e., a relatively small volume of medium was available to the tissue for normal metabolic activity.

In another *in vitro* assay, the cytotoxic activity of mouse T-lymphocytes was suppressed by a 2-h exposure (1.5 mW/cm^2) to 450-MHz fields, modulated at frequencies between 16 and 100 Hz (Lyle *et al.* 1983). Peak suppression occurred at 60-Hz modulation, with smaller effects at 16, 40, 80, and 100 Hz. The exposed cells recovered full cytotoxic activity 12.5 h after the termination of exposure. This result demonstrated an inhibitory but reversible effect on a cell-mediated immune response by modulation frequencies.

5.7.5.4 Sinusoidal ELF and Sub-ELF Signals

Most of the studies reviewed above demonstrate an absolute requirement for low-frequency sinusoidal modulation of the RF carrier wave in order for the signal to be effective biologically. For completeness, several reports are mentioned that describe biological effects of exposure to low frequencies in the absence of an RF carrier wave. Bawin and Adey (1976, 1977) exposed chick and cat cerebral tissue for 20 min to 1, 6, 16, 32 or 75 Hz at electric field gradients of 5, 10, 56, and 100 V_{p-p}/m in air. Only two frequencies, 6 and 16 Hz, caused a reduction in calcium-ion efflux at 10 and 56 V/m for the chick tissue, and at 56 V/m for the cat tissue. Because all other combinations produced no field-induced responses, the authors described "amplitude and frequency windows" for calcium-ion efflux. Electric field gradients within the tissue were estimated to be 10^{-5} V/m. The field-induced reduction in efflux is in contrast to the enhancement caused by modulated RF carrier waves. Nevertheless, the frequency dependence observed in the two studies was similar, which suggests an interaction with a common substrate as the site of interaction.

Blackman *et al.* (1982) used chick brain to study the influence of 16-Hz signals at 15 intensities between 1 and 70 V_{p-p}/m on the efflux of calcium ions. Two intensity regions that included 5, 6, and 7.5 V/m and 35, 40, 45, and 50 V/m caused enhanced efflux. No field-induced effects were seen below (1, 2, and 3.5 V/m), between (10, 20, and 30 V/m), or above (60 and 70 V/m) the two effective intensity regions. Moreover, 1- and 30-Hz signals at 40 V/m caused no change in efflux. This finding is consistent with the reports of multiple-intensity regions of enhanced efflux caused by modulated RF radiation (Blackman *et al.* 1980b, 1981). In addition to the intensity response, the frequency dependence corroborated reports by Bawin and Adey (1976) for low-frequency signals, and by Bawin *et al.* (1975) and Blackman *et al.* (1979) for modulated RF fields.

In these two low-frequency studies, the cause of the slight difference in effective intensities is unknown. The major disagreement in the results of Bawin and Adey (1976) and Blackman *et al.* (1982) is the direction of the change in efflux; the latter authors state that the "cause may be found in the slightly different preparations and procedures used in the two laboratories."

Several research groups have reported biological changes induced by low-frequency, sinusoidally oscillating magnetic fields. The myxomycete *Physarum polycephalum* has a longer mitotic cycle and reduced respiration rate after chronic exposure to 2.0-gauss magnetic fields at 75 Hz (Goodman *et al.* 1979). Human fibroblasts in culture exposed to sinusoidally varying magnetic fields for a wide range of frequencies (15 Hz to 4 kHz) and amplitudes (0.25 to 5.6 gauss) exhibit enhanced DNA synthesis (Liboff *et al.* 1984). Fruit flies *(Drosophila melanogaster)* preferred not to deposit eggs in a 10-gauss, sinusoidally varying 50-Hz magnetic field; similar exposure during development of the egg produced less viable eggs and pupae in the exposed samples than in controls (Ramirez *et al.* 1983). These results suggest that low-frequency, sinosoidally varying fields may alter fundamental biological processes.

Low-frequency, pulsed magnetic fields have also been reported to produce alterations in diverse biological systems. These systems include the developing chick embryo (Delgado *et al.* 1982; Ubeda *et al.* 1983), *Drosophila* egg laying and mortality (Ramirez *et al.* 1983), the de-differentiating amphibian red blood cell (Chiabrera *et al.* 1979), transcription in the *Dipteran* chromosome (Goodman *et al.* 1983), nerve cells in culture (Dixey and Rein 1982), and mouse bone cells in culture (Luben *et al.* 1982). Many of these studies used an intricate pulsed waveform, which has been used in therapeutic devices for bone nonunions. All the studies used pulse repetition rates below 500 Hz, with most below 100 Hz. Recently, Liboff *et al.* (1984) questioned the need for the particular wave shapes because it appears that the essential element is the low-frequency field.

5.7.5.5 Summary

Many reports of effects of RF fields that are amplitude modulated at very low frequencies have not been independently corroborated. The major exception is calcium-ion efflux from chick brain tissue *in vitro* at intensity levels far below those that cause heating. This exception, combined with the results of studies of brain biochemistry and EEGs in animals and with synaptosomes and human neuroblastoma cells in culture, provides evidence that CNS tissue from several species, including human beings, is affected by low-intensity RF fields sinosuoidally amplitude modulated at specific low frequencies (Table 5-23). The physiological significance of these field-induced effects is not established.

5.7.6 Unresolved Issues

In addition to the CNS-related changes, amplitude-modulated RF fields have been reported to alter an immune response and a pancreatic tissue function. These reports with diverse biological systems are without apparent connection to each other except for the physical agent causing the change. The biological effects of frequency-modulated RF radiation, e.g., FM radio signals, are not known. The reports cited above of Merritt and co-workers indicate that pulsed square-wave modulation may not cause calcium-ion efflux, whereas data from the Bawin *et al.* and Blackman *et al.* studies show that sine wave modulation is effective.

No report has yet described a mechanism of action in sufficient detail to identify the conditions necessary and sufficient to explain unequivocally calcium-ion efflux in the brain or the other biological changes caused by modulated RF fields. The response to specific frequencies and intensities is unusual and at present unexplained. This response to amplitude-modulated RF radiation or to sub-ELF signals alone may be a true field effect at a very low SAR and at biologically relevant frequencies, i.e., in the range of frequencies normally present in the EEG. The frequency-specific nature of the responses provides evidence against heat as the underlying cause. The unusual, multiple-intensity-range response challenges standard dose-response analyses, and by its very nature, may prohibit the invocation of threshold levels.

Other areas of unresolved issues include comparisons of CW vs. PW microwaves under identical exposure conditions. Such studies would help determine if the differences seen by Wangemann and Cleary (1976) were due to different exposure conditions or to the irradiation parameters (CW or PW). There is also a paucity of information on the effects of RF radiation at different frequencies, particularly at frequencies of environmental importance. Studies at different frequencies would help to determine the reasons for differences in effects at similar SARs. Such studies might help explain why Wangemann and Cleary (1976) reported serum chemistry changes in rabbits at 0.8 W/kg (2450 MHz), and why Lovely *et al.* (1977) reported no change in serum chemistry values in rats at 1 W/kg (918 MHz).

There are also data such as those reported by Boggs *et al.* (1972) where the results from microwave heating to a predetermined temperature are different from those resulting from the same temperature produced by other means of heating. Perhaps there are differences in the uniformity of heating or in the rate of heating which would account for these differences. In addition, a study by Deficis *et al.* (1979) reported elevated serum triglyceride and β-lipoprotein levels in mice exposed to 2450 MHz at 1.5, 3.3, or 4 mW/cm², but not at 1 mW/cm². Because the exposures were conducted in a multimodal cavity, SAR values were not reported and cannot be predicted. If this study is repeated, particular attention should be given to dosimetry. An alternative is to make or report dosimetric measurements in the exposure system used.

The reported effects on thyroid function at 3.75 W/kg for 60 h contrasted with no effect at 6.25 W/kg for 16 h (Parker 1973) suggests that the total amount of energy absorbed may also be an important consideration. Additional studies could define further the relative importance of dose rate compared with total dose.

Table 5-23. Summary of Studies Concerning Biological Effects of Low Frequency Modulation of RF-Radiation

Effects	Species	RF (MHz)	Modulation (Hz)	Intensity (mW/cm²)	Time (min)	SAR (W/kg)	Reference
Altered calcium-ion efflux in brain tissue *in vitro*							
frequency specificity	Chicken	147	6-20	1-2	20	0.002*	Bawin *et al.* (1975)
influence of pH and lanthanum	Chicken	450	16	0.75	20	0.0035*	Bawin *et al.* (1978)
frequency and intensity specificity	Chicken	147	16	0.83	20	0.0014*	Blackman *et al.* (1979)
intensity specificity and sample spacing	Chicken	147	9, 16	0.83	20	0.0014*	Blackman *et al.* (1980a)
theoretical analysis of sample spacing	Chicken	147	16	0.83	20	0.0014	Joines *et al.* (1981)
intensity specificity	Chicken	450	16	0.1-1	20	0.0005-0.005*	Sheppard *et al.* (1979)
two intensity ranges	Chicken	50	16	1.5 3.6	20	0.0013 0.0035	Blackman *et al.* (1980b)
theoretical analysis of RF dependence	Chicken	50 147 450	16	—	20	~0.001	Joines and Blackman (1980); Athey (1981); Joines and Blackman (1981)
test of predictions of theoretical analyses	Chicken	147	16	0.37 0.49	20	0.0006 0.0008	Blackman *et al.* (1981)
no effect for pulse modulation	Rat	1000	16', 32'	0.5-15	20	0.15-4.35	Shelton and Merritt (1981)
no effect for pulse modulation	Rat	1000 2450	16' 8', 16', 32'	1, 10 1	20	0.29-2.9 0.3	Merritt *et al.* (1982)
change in calcium efflux kinetics in synaptosomes	Rat	450	16	0.5	10	—	Lin-Liu and Adey (1982)
frequency and intensity specificity in cultured neuroblastoma cells	Human being	915	16	—	30	0.05	Dutta *et al.* (1984)
Altered calcium-ion efflux in brain tissue *in vivo*							
no effect for pulse modulation	Rat	2060	8', 16', 32'	0.5-10	20	0.12-2.4	Merritt *et al.* (1982)
change in efflux kinetics from awake animal	Cat	450	16	3	60	0.29	Adey *et al.* (1982)
Changed EEG patterns	Rabbit	1.2 5.0	15 14	500 V/m 500 V/m	120 x 6wk 120 x 6wk	— —	Takashima *et al.* (1979)
No change in behavior	Chicken	450	3, 16	1, 5	23	0.2, 1.0*	Sagan and Medici (1979)
Suppressed T-lymphocyte activity	Mouse	450	16-100	1.5	120	—	Lyle *et al.* (1983)
Altered calcium ion efflux in pancreatic slices *in vitro*	Rat	147	16	2	60-150	<0.075	Albert *et al.* (1980)

*Est. SAR.
'Square wave.

Excerpts from Effects of Continuous Low-Level Exposure To Radiofrequency Radiation On Intrauterine Development in Rats, S. Tofani et al., Health Physics, 1986, Vol 51, No. 4, page 489-499.

This study shows that at levels much below the ANSI standard that fertility and fetal development problems can occur.

It emphasizes that Congress should begin to deal with the question of what to do if there are really adverse health effects, given that telecommunications is such a pervasive aspect of our society.

0.08 Watts per kilogram of body weight is the "safe" level set by the ANSI standard for the general population.

Page 494 gives the exposure level of the pregnant rats at about 0.00011 Watts per kilogram of body weight, about 1/700th of the 0.08 Watts per kilogram of body weight considered "safe" for the general population.

Page 492 shows only 50% of the pregnant exposed rats had viable fetuses.

Page 496 shows that depending on length of exposure that 24% to 52% of the exposed rats had incomplete cranial development compared to 5.7% for the controls. This suggests that increased radiofrequency exposure, even at base station levels could result in infertility problems and fetal development problems.

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EFFECTS OF CONTINUOUS LOW-LEVEL EXPOSURE TO RADIOFREQUENCY RADIATION ON INTRAUTERINE DEVELOPMENT IN RATS

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Abstract—To assess the effect of low-level radiofrequency radiation on pregnant rats, gravid dams were exposed continuously to 0.1 mW cm^{-2} at 27.12 MHz during different periods of pregnancy. Biological assays consisted of determining pre- and post-implantation losses and the effects on maternal body weight increase. Fetal parameters monitored included sex, mean viable fetal weight on Day 20 of gestation, external, skeletal and visceral fetal malformations, anomalies and variations. Dosimetric evaluations were made in terms of average specific absorption rate (SAR) and basal metabolic rate (BMR). Findings included a considerable increase in the percentage of total resorptions, reduced body weight increase in the exposed dams and incomplete cranial ossification in their fetuses. Results obtained were compared with those shown by other authors. It seems possible to ascribe some of the effects to a specific action of the radiofrequency radiation occurring independently of the rise in temperature. The hypothesis that the exposure time, together with SAR, plays an important role in inducing specific exposure effects due to radiofrequency radiation is presented.

INTRODUCTION

IN RECENT years, considerable research has focused on the interaction of radiofrequency (RF) radiation with living organisms. By 1980, more than 5,000 articles dealt with the subject (Gu80). Most studies concentrate on high-level fields, but few investigate the effects of low levels that do not produce appreciable body temperature increases (Ar84, Wh84). Exposure to levels of RF radiation high enough to raise body temperature poses problems in interpreting results. It is often difficult to distinguish the effects presumably due to a specific RF radiation action from those exclusively due to hyperthermia of the exposed subjects.

Then, in experimenting with field levels high enough to raise body temperature, continuous exposure had to be avoided so physiologically intolerable temperatures were not reached.

The study of the effects of prolonged exposure to low levels of RF is very important since it represents true exposure conditions of sizeable populations.

This type of study takes on further significance since several nations are in the process of establishing standards to regulate exposure to RF radiation (IRPA84).

The prenatal period was chosen in order to evaluate the effect of continuous low-level exposure. For this purpose, pregnant rats were exposed to continuous low-level (0.1 mW cm^{-2}) RF radiation at a frequency of 27.12 MHz during different periods of pregnancy. Recently other authors (Di75; La82) have studied the effects connected with non-continuous exposure to 27.12-MHz RF radiation during different gestation stages.

INSTRUMENTS, MATERIALS AND METHODS

Sexually mature, 12- to 13-week-old, CD Sprague-Dawley rats† were given a pelleted diet‡ and water *ad libitum*, and they were maintained under a 12-h light,12-h dark cycle at 22 ± 2°C.

Four sexually mature nulliparous females were caged overnight with each male and checked the following morning between 8:30 and 9:30 a.m. for the presence of sperm in the vaginal smear. The day sperm was detected was considered Day 0 of gestation. Sixty mated females were marked on different sides of the body with a picric acid and water solution and randomly assigned to an exposed or control group.

Four groups were formed: *A*, *B*, *C* and *D*. Groups *A* and *B* were composed of 20 females each, groups *C* and *D* of 10 each. Group *A* females were sham-exposed and considered the control group. Group *B* was exposed continuously for the pregnancy period from Day 0 through Day 20. Group *C* was exposed continuously from Day 0 through Day 6 and group *D* from Day 6 through Day 15 of gestation. Groups *C* and *D* were exposed to determine if RF radiation exercises a selective influence on the implantation or organogenesis phases.

The animals were exposed to RF radiation at a frequency of 27.12 MHz, an electric field strength of 20 V m^{-1} and a magnetic field strength of 0.05 A m^{-1} (power density 0.1 mW cm^{-2}). The RF radiation was generated by a 27.12-MHz power generator§ and a radiant coil antenna.‖

The exposed dams were co-housed in lidless plastic boxes measuring 80 × 60 × 35 cm.

The antenna stood 1.50 m from the rat box at floor level so as to provide an exposure under not purely inductive field conditions. At this height, it was possible to produce homogenous RF radiation levels on a surface large enough to contain two rat boxes side by side. Since every rat box contained 10 females at the most, 20 females of the *B*, *C*, and *D* groups could be exposed simultaneously. The experimental apparatus operated continuously for 45 d, thereby exposing all the animals.

At the same time, the Group *A* animals were sham-irradiated in another room. During the pregnancy period when they were not subjected to irradiation, the group *C* and *D* animals were placed in group *A*'s room.

The two rooms used for irradiation and sham-irradiation had the following environmental conditions: temperature 22 ± 2°C, relative humidity 60 ± 20%, 15 air changes per hour (filtered with absolute filters), and a circadian cycle using 12-h light and dark intervals.

To ensure correct evaluation of the results, particular care was taken in measuring the exposure levels. Dosimetry consisted of:

(1) Measuring field levels and verifying their uniformity over the entire space provided for the rats, with a field meter instrument†[(a)] equipped with an isotropic electrical sensor†[(b)] and with an isotropic magnetic sensor†[(c)]. The uniformity was found to be adequate within a margin of 1 dB.

(2) Verifying the absence of different interfering frequencies, due to environmental background or to higher-order harmonics emitted by the generator. This was done with a spectrum analyzer,‡[(a)] and mainframe digital memory,‡[(b)] which had a specially designed biconical section antenna appropriately calibrated. The test provided negative results.

(3) Evaluating the 50-Hz field levels present in the rat boxes, with an isotropic sensor†[(d)] appropriately calibrated. It detected a low ambient level not influenced by running the generator.

(4) Checking the rectal temperature of all the rats of the *A*, *B*, *C* and *D* groups every day of pregnancy. Measurements were taken to a depth of 1 cm with an optical fiber probe‡[(a)] connected with a fluoroptic thermometer.‡[(b)] The system permitted an accuracy of 0.1°C. The temperature was found to stay within physiologically normal limits.

The body weight of each dam was recorded on Days 0, 6, 10, 15, 18 and 20. The Day 20 body weight recording also was made for the net weight of the uterus and concepta.

All dams were sacrificed by cervical dislocation between 2:00 p.m. and 5:00 p.m. on Day 20 of gestation and autopsied to record number of corpora lutea, number of implantations after Salewsky's staining, number of viable fetuses, number of dead fetuses, fetal body weight and sex of the fetuses. Pre-implantation losses were calculated for each dam by subtracting the number of implantations from the number of corpora lutea. Post-implantation losses for each dam were derived by subtracting the number of viable fetuses from the number of implantations. The presence of corpora lutea gave evidence of the pregnancy in cases in which total resorptions were observed.

Subsequently, the presence of external variations, anomalies or malformations was recorded for each fetus. Fifty percent of each litter was cleared (Ci62, St64) for skeletal examination and the other 50% was fixed for visceral examination by Wilson's technique (Wi65).

The litter average was the unit chosen for data analysis except for fetus malformations, anomalies and variations, in which case the fetus was considered the experimental unit. Test and control group composition was such as to provide a sufficient number of experimental units (single litters) for suitable statistical evaluation (Pa80).

Statistical analysis of the results was by: (1) Dunnett's multiple comparison test (Du55) for mean maternal and fetal weights; (2) Mann Whitney's U test (Si56) to compare mean number of corpora lutea, mean number of implantations, mean body-weight increase, mean number of viable fetuses, as well as pre- and post-implantation losses; and (3) chi square test to compare the number of dams with 100% resorptions, number of dams with viable fetuses, number of fetuses with variations, anomalies or malformations, and percentage of male and female fetuses. The level of significance was set at $p < 0.05$ for all statistical tests.

RESULTS

(a) *Biological evaluations*

The following results for all dams in the four experimental groups are given in Table 1: corpora lutea, implantations, number of dams with total resorptions, number of dams with viable fetuses and pre- and post-implantation losses. The presence of dead fetuses was not observed.

Since the experimental unit was the litter, the data in the tables are means of litter means or means of litter percentage. The standard error which affects every value is indicated between brackets.

The data in this table show that exposure to RF radiation caused a high number of dams with total resorptions in all treated groups. This effect had an incidence of 50% in the dams of groups *B* and *C* and of 20% in the dams of group *D*, while no dam of control group A had total resorptions.

Table 2 shows the following results concerning only the dams with viable fetuses at Day 20 of gestation for all experimental groups: corpora lutea, implantations, viable fetuses, pre- and post-implantation losses, weight and sex of fetuses. In this table, too, the values are means of litter means or means of litter percentage.

From the values reported in Table 2, the significant increase of post-implantation losses, indicated in Table 1 for *B* and *C* groups, must be attributed almost exclusively to the dams with total resorptions. In fact, the post-implantation losses were not significant in the *B* and *C* group dams with viable fetuses on Day 20 of gestation.

The agreement between the results relating to the total resorptions in the *C* group compared with those of the *B* group, and the non-significant increase in the number of total resorptions in the *D* group, suggests that this effect is linked to exposure during the very early stage of the egg's development, causing unfavourable conditions for implantation.

Moreover, since this effect does not result in a significant generalized increase of the post-

† Charles River Italia S.p.A., V. Indipendenza 11-13, Calco 22050, Como, Italy.

‡ GLP 4RF25, Italiana Mangimi, V.G. Galilei, 6-Settimo Milanese (MI), Milan, Italy.

§ Sanitas Thermosan 1000 RF generator; Sanitas Electric, Via A. Da Guissano 1, 20145 Milano, Italy.

‖ Siemens Diplode antenna; Siemens AG UB MED, Henkestrasse 127, D-8520 Erlangen, Federal Republic of Germany.

†(a) Aeritalia Metering Instrument 11: 307; (b) Aeritalia Model RV 14, (c) Aeritalia Model RV 17; and (d) Aeritalia Model RV 19-3; Aeritalia, Avionic Sector, 10072 Caselle Torinese, Italy.

‡(a) Hewlett Packard 8558 B spectrum analyzer, and (b) Hewlett Packard 853 A mainframe digital memory; Hewlett Packard Co., P.O. Box 10301, Palo Alto, CA 94303.

‡(a) Luxtron Model LMC, (b) Luxtron Model 1000A; Luxtron, 1060 Terra Bella Avenue, Mountain View, CA 94043.

Table 1. Data for all dams of the four experimental groups. Values are means of the means of the litter or means of percentages per litter. Affecting every value, the standard error (S.E.) *is indicated in parentheses*

Group	Exposure period (Day)	No. gravid females	Corpora lutea: Mean (S.E.)	Implantations: Mean (S.E.)	% Pre-implant. losses: Mean (S.E.)	% Post-implant. losses: Mean (S.E.)	Dams with viable fetuses No.	Dams with viable fetuses %	Dams with total resorptions: No.	Dams with total resorptions: %
A	-	20	11.00 (0.86)	9.35 (1.01)	16.63 (4.89)	6.86 (2.04)	20	100	0	0
B	0-20	20	10.40 (0.70)	8.20 (0.88)	24.65 (5.23)	58.44*** (10.26)	10‡‡	50	10‡‡	50
C	0-6	10	11.10 (0.61)	8.80 (0.80)	20.50 (5.82)	51.67* (16.19)	5‡‡	50	5‡‡	50
D	6-15	10	12.30 (1.04)	10.60 (1.20)	15.59 (5.15)	37.80 (14.14)	8	80	2	20

Mann Whitney's "U" test (one-tailed) * $p < 0.05$; *** $p < 0.001$ chi 2 test ‡‡ $p < 0.01$

Table 2. Data for dams of the four experimental groups with viable fetuses at Day 20 of gestation. Values are means of means of litter or means of percentages per litter. Affecting every value, the standard error (S.E.) *is indicated in parentheses*

Group	Exposure period (Day)	No. of dams with viable fetuses	Corpora lutea Mean (S.E.)	Implantations: Mean (S.E.)	% Pre-implant. losses: Mean (S.E.)	Viable fetuses: Mean (S.E.)	% Post-implant. losses: Mean (S.E.)	Fetal weight(g): Mean (S.E.)	Sex %M	Sex %F
A	-	20	11.00 (0.86)	9.35 (1.01)	16.63 (4.89)	8.80 (0.96)	6.86 (2.04)	3.78 (0.13)	47	53
B	0-20	10	11.10 (1.05)	9.80 (1.06)	12.87 (4.56)	8.3 (1.37)	16.89 (7.80)	3.75 (0.06)	52	48
C	0-6	5	12.00 (0.95)	9.60 (1.21)	19.89 (7.65)	9.4 (1.36)	3.33 (0.2)	3.71 (0.38)	53	47
D	6-15	8	13.25 (1.05)	12.00 (0.95)	9.07 (3.13)	9.88 (1.84)	22.25 (12.18)	3.55 (0.21)	48	52

implantation losses in all the exposed litters, but in a total post-implantation loss in some dams, it leads us to suppose that the effects must be ascribed to an action of RF radiation on the dam.

Table 3 reports the body weight on Days 0 and 20 of gestation; weight on Day 20 of gestation excluding gravid uterus, absolute increase from Day 0 through 6, 6 through 10, 10 through 15, 15 through 18 and 18 through 20, 0 through 20, and the increase in the same period excluding gravid uterus.

Data reported in Table 3 refer to the dams that had viable fetuses on Day 20 of gestation. The comparison between the body weight increases at different gestational stages is justified since the mean number of viable fetuses of such dams is similar for the four groups.

Values reported in Table 3 are means of litter means. On Days 0–6, the weight increased relative to the animals of the exposed groups (*B* and *C*), whose weight was significantly lower.

In the following period (Days 7–10), the weight increase was lower in the exposed animals of groups *B* and *D* compared to those of the control group.

The animals of *B* group, irradiated from Day 0 to Day 20 of gestation, showed a smaller increase from Day 18 through Day 20.

The increment of body weight in the period from Day 0 to Day 20 of gestation, net of uterus and concepta, is significantly lower in the three exposed groups compared to the control one; in particular it is lower for the B group that was exposed for the longest period.

Results shown in Table 3 suggest that the exposure to RF radiation produces a smaller increase in the dams' body weight, reflecting a negative influence on their health.

The body weight increase of the dams which had total resorptions was not considered because they could not be compared to the control group.

Table 4 gives the data from the external, skeletal and visceral examinations of the fetuses. The percentage reported in the table refers to the number of fetuses examined.

The only finding was an incomplete ossification of the cranial bones. This variation was found in all exposed groups with a much higher incidence than in the control animals or in general observations of animals of this strain. The few external and visceral malformations did not have any correlation to RF exposure.

In the tables only p values below the statistical significance level ($p < 0.05$) are reported.

(b) *Dosimetric evaluations*

The effects of exposing live organism (animals) to RF radiation are customarily measured by calculating the specific absorption rate of energy (SAR). The SAR, when RF radiation power density is equal, is essentially due to: radiation frequency, animal size, and its orientation with respect to polarization plane if present.

The SAR is strictly linked to RF radiation energy conversion into thermal energy. This is why, when the object exposed has no thermoregulatory mechanisms, the evaluation of SAR is merely a matter of measuring heat (Ch82).

Using the SAR, it is easy to calculate the amount of energy released to a whole organism and, when the SAR is compared to its basal metabolic rate (BMR), it provides a way to estimate radiation hazard. SAR interpretation was used to set exposure limits in national standards and establish international guidelines (ANSI82; IRPA84). Thus, the study of RF radiation effects on animals and their correlation through SAR is of significance.

Recent studies have simulated man's exposure using animals or figurines (Gu80; Gu84), taking into account the wavelength in relation to the size of the exposed subject (Du80) and using the SAR to guarantee identical exposure conditions.

In this experiment, given the rats' mobility within their boxes, an upper SAR limit was set presuming continuous exposure conditions to a linearly polarized electrical field in the direction of the main body axis. Since the power density incidence was 0.1 mW cm^{-2} and was uniform over the surface available to the rats, the value of 1.1×10^{-4} W kg^{-1} for rats weighing 300 g each was obtained from Du78. This value need not be corrected for near field exposure conditions (Ch82), because the field level was uniform in all positions the rats could take. Local energy uptake and, hence, relative SAR increases in embryos, for example, can be ruled out because of the size of body parts compared to the radiation wavelength over the whole body (about 1 m). SAR increases due to a multibody effect (Ga79) are excluded for the same reason. The mean SAR value is compared to BMR, which is 6.51 W kg^{-1} for these animals (Du78). It is clear that the mean SAR is insignificant when compared to the BMR.

Specific absorption Rate
= 0.00011 watts/kg

Table 3. Body weight and body weight increase of the dams of the four experimental groups with viable fetuses at Day 20 of gestation. Values are means of the means of the litter. Affecting every value, the standard error (S.E.) is indicated in parentheses

Group	No. of dams with viable fetuses	BODY WEIGHT (g) Mean (S.E.)			BODY WEIGHT INCREASE (g) Mean (S.E.)						
		Day 0	Day 20	Day 20 (§)	0–6	6–10	10–15	15–18	18–20	0–20	0–20 (§)
A	20	[illegible]	343.6	285.8	17.6	2[illegible]	25.5	27.[illegible]	22.6	112.[illegible]	54.8
		(4.1)	(5.8)	(6.0)	(1.2)	[illegible]	(2.5)	(2.3	(2.[illegible]	(4.7)	(4.5)
B	10	232.[illegible]	307.9°°	254.3°	9.2*	10.0*	21.3	20.6	14.6*	75.7***	22.1**
		(8.3)	(10.3)	(10.4)	(3.1)	(5.1)	(3.5)	(4.8	(3.4	(8.1)	(10.6)
C	5	244.8	335.4	281.8	11.2**	10.6	12.6*	36.6	17.0	90.6*	37.0*
		(10.4	(10.6)	(11.6)	(1.9)	(5.1	(4.9)	(6.1	(5.2	(9.3)	(9.1)
D	6	235.[illegible]	326.6	273.5	24.6	[illegible].9**	27.8	19.3	16.4	92.8*	37.6*
		(13.5	(16.9)	(12.4)	(5.4)	(1.6)	(6.1)	(8.2	(4.1)	(9.6)	(5.0)

(§) Final body weight excluding gravid uterus

Mann-Whitney's "U" test (one-tailed) * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Dunnett's test ° $p < 0.05$; °° $p < 0.01$

Table 4. Data from the external, skeletal and visceral examinations of the fetuses. Data are numbers of fetuses or percentages of the number of examined fetuses

Group	Exposure period (Day)	EXTERNAL EXAMINATION: No. examined fetuses	Fetuses with malformations No.	Fetuses with malformations %	Fetuses with anomalies No.	Fetuses with anomalies %	SKELETAL EXAMINATION: No. examined fetuses	Incomplete cranial ossification (variations) No.	Incomplete cranial ossification (variations) %	Wavy ribs No.	Wavy ribs %	VISCERAL EXAMINATION: No. examined fetuses	Fetuses with malformations No.	Fetuses with malformations %
A	-	176	0	0.0	0	0.0	88	5	5.7	0	0.0	88	0	0.0
B	0 - 20	84	0	0.0	2[§]	2.4	41	10[‡‡]	24.4	0	0.0	43	1[·]	2.5
C	0 - 6	47	0	0.0	0	0.0	24	9[‡‡‡]	37.5	0	0.0	23	0	0.0
D	6 - 15	79	1[£]	1.3	2[§]	2.5	40	21[‡‡‡]	52.5	2	5.0	39	0	0.0

£ Umbilical hernia
§ Skin hematoma
· Lateral ventricles hemorrhage

Chi square test: ‡‡ $p < 0.01$
‡‡‡ $p < 0.001$

Considering the effects this study detected, as well as the dosimetric evaluations, it is evident that mean SAR is an inadequate parameter in forecasting the potential biological risks of exposure to RF radiation. This conclusion agrees with that of the World Health Organization (WHO81). Moreover, since the power dissipated as heat in the exposed animals was slight, the effects may have been due to non-thermal interaction. Such potential effects are also considered by the International Radiation Protection Association (IRPA84) in its recent recommendations on exposure limits.

DISCUSSION

Better interpretation of the results can be made through comparison with data published by other authors. It is particularly difficult to reach general conclusions on these effects since few studies on the evaluation of effects after exposure to 27.12-MHz RF radiation have been published.

The amount of data available for comparison is greater if it is extended to studies done at different frequencies. However, another parameter, wavelength, is introduced, which could influence how the effects themselves are induced. Moreover, all studies examined refer to high field level exposures, which produce an appreciable rise in the internal temperature of the exposed animals.

One remaining point of inquiry relates to the existence of effects that can be attributed to RF radiation exposure rather than to temperature caused by exposure.

Useful clues to this connection can be drawn by comparing the results of this study, obtained with an insignificant SAR when compared to BMR, with those obtained by other authors investigating the same effects.

Dietzel (Di75) exposed groups of pregnant rats, one group per day, from Day 1 through 16 of pregnancy to 27.12-MHz RF radiation for 5 or 10 min each, until he obtained predetermined rises in rectal temperature.

Chernovetz (Ch77) exposed groups of pregnant rats on different days of pregnancy from Day 10 through 16, exposing each group for 20 min at 2.45-GHz RF radiation (SAR = 31 W kg^{-1}), producing a significant rise in the colonic temperature. He compared these effects obtained with those cause by exposing the same number of pregnant rats on the same days of pregnancy to infrared radiation, causing the same colonic temperature rise.

Lary (La82) exposed groups of pregnant rats on odd days of pregnancy from Day 1 through 15, for an average of 30 min per group, to 27.12-MHz RF radiation (SAR = 11.1–12.5 W kg^{-1}), producing a great increase in the rectal temperature.

Berman (Be84) exposed pregnant rats from Day 6 through 15 for 100 min per day (the total exposure time for each dam was 16 h and 40 min) to high levels of 2.45-GHz RF radiation (SAR = 6 W kg^{-1}), producing an appreciable rise in the colonic temperature.

The increase of post-implantation losses is an effect obtained by most of these authors. In addition to this study, the same effect was observed by Lary (La82), Dietzel (Di75) and Chernovetz (Ch77). These authors noticed a significant increase in post-implantation losses consequent to the RF radiation exposure in the first post-implantation stage; Lary (La82) reported this effect after irradiation on Days 7 and 9, Chernovetz (Ch77) after exposure on Day 11 and Dietzel after irradiation starting from Day 7 to Day 16 with a total average exposure time of 10 min.

Attributing the increase in post-implantation losses to a specific action of RF radiation seems to be confirmed by Chernovetz's experiments (Ch77). He noticed a significant increase in post-implantation losses only in rats exposed to RF radiation.

In the same way, Chernovetz's results (Ch77) concerning the dependence of fetal weight decrease upon the rise in temperature of the dam, rather than upon the specific action of RF radiation, is confirmed by the observation of this effect by Lary (La82), Dietzel (Di75) and Berman (Be84), though it was not observed during the experiment reported here.

The interpretation of data relative to teratogenic effects (i.e. malformations, anomalies, variations) does not seem simple.

Dietzel (Di75) observed an increase in the frequency of tail and extremity malformations. He hypothesized that temperature rise after exposure to RF radiation caused inhibition of DNA synthesis.

Lary (La82) noticed a significant increase in malformations, major skeletal abnormalities and skeletal variations, and Berman (Be84) observed a non-significant increase in malformations and a significant ossification delay of the sternum in the fetuses of exposed dams.

Chernovetz (Ch77) did not observe any structural abnormalities during a gross teratological examination.

However, during this study, a significant increase in the numbers of fetuses with incomplete ossification of cranial bones was observed.

These comparisons suggest the following considerations: (1) a prolonged exposure to 27.12-MHz RF radiation with low SAR, as carried out in this study, produces an effect (post-implantation losses) comparable to that observed by Lary (La82), which was caused by brief exposure to 27.12-MHz RF radiation with high SAR; (2) the effect cited in point (1) seems due to a specific action of RF radiation rather than the rise in temperature produced. Therefore, the time of exposure seems to be of great importance in inducing specific effects.

The hypothesis that the time of irradiation is a fundamental parameter in inducing effects specifically due to RF radiation exposure, though the microwave region, was recently presented by Fröhlich (Fr80). He regards the electric vibrations of biological systems as the basis of a general theory on specific effects. Such a theory assumes that a biological system can store energy to trigger subsequent events. At low rates of supplied energy, the system needs a very long time to store enough energy to cause this trigger effect.

The possibility that the effects observed in this study could be dependent upon length of exposure and could result from interaction processes similar to those proposed by Fröhlich (Fr80) needs deeper theoretical and experimental studies. It is necessary, in order of importance, (1) to experimentally define the modalities of the dependence of the occurrence of specific effects on time and radiation frequency and (2) to verify the possible existence of a minimum SAR threshold under which effects were not noticed even with a prolonged exposure time.

CONCLUSIONS

Gravid rats continuously exposed to 27.12-MHz RF radiation and a power density of 0.1 mW cm^{-2} during different periods of pregnancy had a significant increase in resorption (post-implantation losses).

Effects of prolonged exposure to low-level radiation on the dam's health was hypothesized, considering that the increase in resorptions was not found in all the exposed litters homogeneously, but depended upon total resorptions in some litters and significant decreases in the body weight increment of the dams during the first week of exposure.

In the fetuses of the three exposed groups, an incomplete ossification of cranial bones was also noticed.

Present data do not permit an exhaustive biological interpretation on the observed effects, but by comparing the results obtained with other authors' studies, it seems that the irradiation time plays an important role in inducing specific effects consequent to the RF radiation exposure.

Further investigations would be warranted to identify the mechanisms of interaction between RF radiation and biological organisms. By defining additional physical parameters to be used with the SAR, such a study would be considered particularly important where very low levels of RF radiation (i.e. those not causing significant rises in body temperature) are concerned.

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Shows NO Research on Modulated RF & Melatonin

5.6.3. Unmodulated Radiofrequency Fields

No data were found.

5.6.4. Summary

The preceding studies show that pulsed magnetic fields inhibit the hormonal action of parathyroid hormone, which is to increase the concentration of cAMP, decrease the rate of collagen synthesis in bone cell cultures, and increase the rate of bone resorption. This action occurs at plasma membrane PTH receptors. These experiments indicate that pulsed magnetic fields interfere with the signal transduction system which is mediated by the binding of PTH to its plasma membrane receptor. Inasmuch as cell proliferation is also thought to be mediated through the activation of multiple signal transduction systems, it is possible that ELF also has the potential for causing changes in some of these systems and thus could have an effect on cell growth including the growth of preneoplastic lesions and tumors.

5.7. MELATONIN AND OTHER HORMONES

In the previous section, the effects of ELF fields on parathyroid hormone-dependent aspects of collagen synthesis were examined. Another endocrine gland, the pineal, and its hormones have been associated with certain forms of breast and prostate cancer in humans and with cancer induction in animals.

5.7.1. Background: Melatonin and Cancer

Various investigators have reported an association of melatonin secretion with cancer in humans, particularly certain forms of prostate and breast cancer. Fraschini et al. (1988) examined 254 cancer patients and found increased serum melatonin levels in 99 cases (38.9%), decreased levels in 15 cases (5.9%), and no change in 140 cases (55.2%). Mean serum melatonin levels were significantly higher in cancer patients compared with 98 healthy controls ($p<0.0001$). Regardless of cancer type, serum melatonin levels were higher in cancer patients compared with controls: breast and lung cancer, $p<0.001$; colorectal and gastric cancer, $p<0.005$; soft tissue sarcoma, $p<0.01$; and lymphoma, $p<0.025$. Fraschini et al. (1988) also observed that 66.7% of the patients whose tumors responded to chemotherapy also exhibited increased serum melatonin levels following chemotherapy.

Cohen et al. (1978) proposed that reduced pineal melatonin secretion may be a factor in breast cancer risk. Bartsch et al. (1981, cited in Wilson et al., 1988) reported that women with breast cancer had reduced urinary melatonin levels. Danforth et al. (1982) noted altered melatonin secretion in patients with estrogen-positive breast cancer. Bartsch et al. (1985) reported that men with cancer of the prostate had lower nocturnal melatonin levels than men without the disease. Stevens (1987) suggested that ELF field-induced exposure in rats may result in loss of gonadal downregulation, resulting in increased circulating estrogen levels which may in turn stimulate mammary tissue proliferation and hence increase breast cancer risk.

Tamarkin et al. (1981) reported that melatonin alters dimethylbenz[a]anthracene (DMBA) mammary carcinogenicity. Fifty-day-old rats were given 15 mg of DMBA and were divided into four groups: (1) DMBA + vehicle; (2) DMBA + daily melatonin injections (beginning at day 50); (3) DMBA + pinealectomy (at day 20); and (4) DMBA + pinealectomy + melatonin. Group 2 had significantly fewer mammary tumors than group 1 (controls), indicating that melatonin inhibited carcinogenesis by DMBA; group 3 had more tumors than group 1, indicating that removal of the pineal enhanced carcinogenesis; and group 4 had fewer tumors than groups 1 or 3, indicating that melatonin ameliorated the adverse effects of pinealectomy.

From their studies, which demonstrated that rats constantly exposed to light had increased DMBA-induced mammary tumors, Shah et al. (1984) and Mhatre et al. (1984) concluded that constant light from birth effectively deprives female rats of melatonin and leads to a constant availability of estrogen and elevated circulating prolactin, which increases the turnover of the breast epithelial cells, thereby rendering the breast tissue more vulnerable to the carcinogenicity of DMBA. Some experiments in rodents have shown an increase in mammary cancer on administration of estrogen and of prolactin (Henderson and Pike, 1981).

Immune and neuroendocrine functions cooperate closely to protect the organism from external attacks (Maestroni et al., 1988). Maestroni et al. (1988) demonstrated in experimental studies with mice that melatonin has a general "up-regulatory" effect on the immune system. Exogenous melatonin can counteract the effect of acute stress and/or of pharmacologic corticosterone on antibody production, thymus weight and antiviral resistance. Maestroni et al. (1988) suggest that activation of T lymphocytes is necessary for the immuno-enhancing and anti-stress action of melatonin.